CHAPTER 5

HOT WATER HEATING SYSTEMS

Section I. GRAVITY SYSTEMS

5-1. General.

a. In gravity systems, water flow is produced by the temperature difference between hot water in the supply risers and cooler water in the return risers. The velocity and rate of flow through the system piping is low, so pipe sizes must be relatively large. Gravity systems may have either an open or a closed expansion tank.

b. Distribution supply mains may be located in the basement with up-feed to the radiators and risers (as shown in figure 5-1), or the supply mains may be located in the attic with overhead down-feed supply risers and return mains located in the basement. The return connections are piped into a gravity return main which pitches downward to the return opening in the boiler. Because there are supply and return pipes throughout the building, all radiators are connected in parallel. The water temperature is practically the same in all radiators, except for slight temperature drops in supply mains between the boiler and the end of the circuit. Water temperatures at ends of circuits are lower than the rest of the circuit and are dependent on length of run and heating load. The rate of heat emission is also slightly lower per foot of radiation at the ends of the circuit due to the slight drop in water temperature.

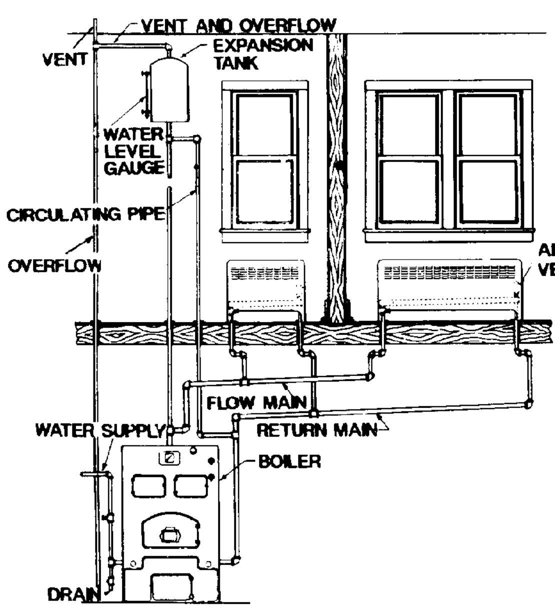

Figure 5-1. Open tank gravity system.

5-2. Equipment.

a. Pressure gauge/thermometer. For this type system, a combination pressure gauge and thermometer is used. Water temperature in the system is indicated on the thermometer scale and the system pressure on a standard gauge dial.

b. Radiator valve. Each radiator has a valve for closing off circulation through the radiator. To prevent freezing of water in a radiator that is closed off, a weep hole is provided to allow sufficient water to circulate at all times. Unlike ordinary steam or water pressure valves, there is no seal in these valves. There is a barrel-like section in which a disk or gate makes a half turn to close the water passage.

c. Radiator air vent. Each radiator has a compression air valve for venting air from the system and radiator. Radiators are tapped at the top-feed and bottom return at opposite ends. Air is also vented from radiators through supply piping up-risers to the high point in the system, from which air is vented through a connection made to the expansion tank.

d. Expansion tanks. All heating systems require an expansion tank to accommodate expansion and contraction of water which occurs as its temperature changes. Excess water is stored in the expansion tank until the water temperature decreases and it is returned to the system. Gravity systems are defined by the type of expansion tank installed: open tanks or closed tanks.

(1) *Open tank system.* In open tank systems, the expansion tank is freely vented to atmosphere. Normally, these systems are limited to operating temperatures of less than 180F.

(2) *Closed tank system.* In closed tank systems (figure 5-2), the expansion tank is airtight, sealed to prevent free venting to atmosphere. As heated water expands, the excess water moves into the tank and compresses the entrapped air thereby increasing the pressure on the system. When the water temperature decreases, the water contracts, air in the tank expands, the excess water returns to the system, and the pressure drops. A closed expansion tank must be large enough to keep a reservoir of compressed air above the water level to cushion the excess water that enters. Thus the tank must provide space for changes in both water and air volume. A small tank with insufficient air can

cause two undesirable conditions to occur. As the temperature increases, the water expands and the system pressure may increase above the permissible level. This can cause the relief valve to open and waste water. As the temperature drops, the water contracts and the pressure may drop below the permissible minimum. Air will not vent from the system and additional air may be drawn in if the high points of the system have automatic air vent valves.

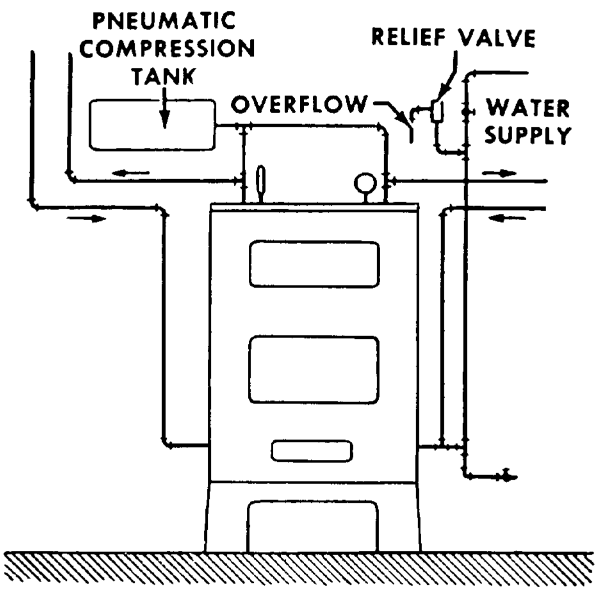

Figure 5-2. Closed tank gravity system.

e. Boiler drain and cleanout openings. The low point in the system has a boiler drain valve and the boiler is provided with rod-out openings so all sediment, rust, and the like can be flushed out readily.

5-3. Startup.

Close all vents, open all radiator valves, and open the water supply valve allowing water to flow until the expansion tank is approximately half filled or until water runs out of the overflow connection. Beginning with the lowest radiators, open vent valves to remove air. Hold a small pail at each vent and close the vent valve when free flow of water occurs. It may be found necessary to add water to the system to enable venting of all radiators as the procedure progresses. A new system should be drained and refilled several times before starting the fire to remove grease, core sand, and other foreign material. In the initial firing of a newly filled system, it is advantageous to bring the system up to temperatures considerably in excess of anticipated operating temperatures. This will tend to expel entrained air from the system water and thoroughly vent the system at start which will eliminate future difficulties due to air pockets. After a new system is in operation for a short period, open boiler drains, since heavy core sand and similar materials have a tendency to flow to this low part of the system. When opening drains and feeding make-up water to a hot water heating system in operation, be careful that flow is not too fast. Otherwise, excessive stress will be set up in the boiler structure due to excessive temperature changes. After the system has been fired approximately 10 days, open air vents again and release air from radiators. Check the system periodically for venting requirements.

5-4. Water level.

Probably the most important consideration in operating a hot water system is maintaining the proper water level in the expansion tank. Frequent observation of the water level should be made. The water level should be low enough in a cold system to allow ample space for heated water to expand.

5-5. Inspection and maintenance.

Operating difficulties of gravity systems are negligible, and corrective measures are seldom required. Air which may accumulate in radiators should be vented periodically to assure consistent heating system performance. If rapid fluctuation or pulsation of pressures should occur, check for system leaks, stoppages and relief valve operation. When a system is to be removed from service, drain the system completely to remove accumulated sediment, rust, etc., and refill with clean water.

Section II. FORCED CIRCULATION SYSTEMS

5-6. General.

a. Forced circulation system piping and equipment (figure 5-3) is similar to that of gravity flow systems, except that pipe and equipment sizes are generally smaller due to increased flow velocities. The general arrangement of the forced flow system differs from the gravity flow type only in that a pump is installed at the termination of the return piping near the boiler. Advantages of using a pump to produce the circulation are that much smaller pipes are required and positive circulation is assured throughout the system.

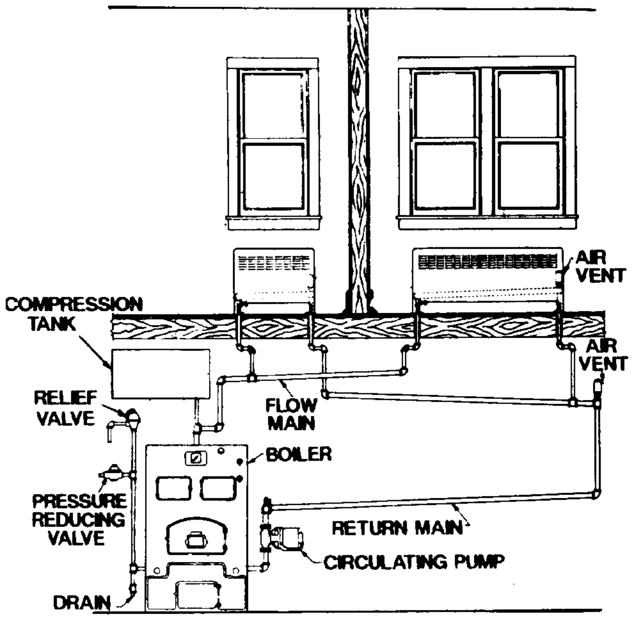

Figure 5-3. Forced circulation system.

b. There are some essential differences in circulation in a forced circulation system as compared with a gravity system. It is necessary to understand what takes place in order to remedy problems that may be encountered in the field. The most important difference is that in the forced circulation system, the circulating force, neglecting gravity effect, is produced locally by the pump. In the gravity system, the circulating force is produced uniformly throughout the system in the vertical runs of piping. A second difference is that the self-regulating property of a gravity system is almost lacking in the forced circulation system. Therefore, if pipe size and radiator connections in the forced circulation system are greatly restricted at some points or improperly sized and balanced for uniform flow, the effect is likely to be serious.

5-7. Equipment.

The principle equipment of a forced circulation system includes a boiler or heat exchanger, radiators or fan-coil units, one or more circulating pumps, an expansion tank, a relief valve, a hand or automatic fill valve to maintain set system pressure, and appropriate controls for pump operation and automatic firing equipment.

a. Hot water pumps. Circulating or booster pumps are usually of the centrifugal type and are installed in the pipe line with flanged fittings. In a system that includes only one pump, each return line is connected to a common pump inlet header through a square-head cock to enable balancing of the system by equalizing return temperatures from various circuits. In large installations immersion thermometers are placed in the return or pro visions are made for inserting immersion type test thermometers near the pump. Circulation pump rotation should be checked to make certain that rotation is in the proper direction. Location of the pump in the return line is suitable for small systems where pump head is low, as in most residential systems. Larger systems require the pump on the supply side of the boiler, with the expansion tank connected to the pump inlet.

b. Expansion tanks. Forced circulation hot water systems almost always employ closed expansion tanks. Since a closed expansion tank is sealed against free venting to the atmosphere, the tank may be above the highest radiator or heat transmitter, or may be below the lowest one. The minimum volume of a closed expansion tank is such that expansion of water due to an increase in temperature is cushioned against a reservoir of compressed air above the water level in the tank. The tank provides space not only for changes in water volume, but also for variations in air volume within the tank due to changes in air pressure. If the closed expansion tank is below the radiators, the tank is larger than if it is above them. The higher the building the larger the air capacity should be within the tank in excess of that required for increase in water volume due to an increase in temperature. The closed expansion tank should be located above the highest heat transfer surface in tall buildings. A closed expansion tank located above heat transfer surfaces of a hot water heating system should be connected by a direct pipe to the flow main leaving the boiler in order to enable air to migrate easily to the expansion tank. In a closed hot water heating system, water tends to absorb air at a rate which increases with an increase in pressure and decreases with an increase in temperature. Means should be provided to adjust and to observe the proportion of air within any closed expansion tank. This includes provision of an air inlet valve, a water gauge, and a relief valve. A source of compressed air for renewing the air cushion is highly desirable, especially in large, high pressure hot water heating systems where it is inconvenient and impractical to drain water in the system to permit introduction of air.

c. Relief valves. All hot water heating systems require proper provision for pressure relief. Equipment can be subjected to excessive pressure by expansion of confined water in the system if: connections to expansion tanks are closed due to freezing or other stoppage causes; the system's expansion tank becomes completely filled with water or; the air volume is inadequate to allow for necessary expansion. A conventional type hot water pressure relief valve which employs a spring-loaded diaphragm to raise a valve seat when water pressure exceeds 30 psig is installed in each system. This valve is located in the cold water supply line between the boiler and the reducing valve. The conventional reducing and relief valve installation does not provide adequate protection for systems in which radiators are at boiler level as in a single story building without a basement where the boiler is installed at grade level in a utility room or similar location. Where radiators are at boiler level, instead of the conventional make-up water connection, an automatic water line regulator is installed in the vertical riser between the main boiler take off and overhead expansion tank. The relief valve is located in the vertical riser at the water line of the regulator.

d. Reducing valves. A reducing valve in the make-up or cold water line to the boiler automatically keeps the closed system supplied with water at the predetermined safe system pressure. The valves are usually factory set at 12 psig pressure, which is equivalent to a static head of 27.6 feet of water, suitable for buildings up to three stories high. The valves can be reset for higher pressures if desired. Thirty (30) psig is the maximum for standard hot water heating system equipment, and the reducing valve setting should be kept as low as possible. The valve should be located at approximately the same level as the top of the boiler.

5-8. Piping systems.

Forced circulation hot water heating systems generally use two-pipe systems. The two-pipe system has two mains: the supply main which feeds water to the risers that serve the heating units, and the return main which collects the water returned from those units. The two mains run side by side; the supply main decreases and the return main increases in size where the branches connect. Since the heating units of a two-pipe system are connected in parallel, a minimum pumping head is required. Also, if throttle valves or restricting orifices are used in the risers, the flow through individual units can be adjusted easily over a wide range. The two-pipe system, however, requires more pipe and fittings than the one-pipe system. Two pipe systems may be classified as either direct-return or reverse-return depending on the direction of the return (figure 5-4).

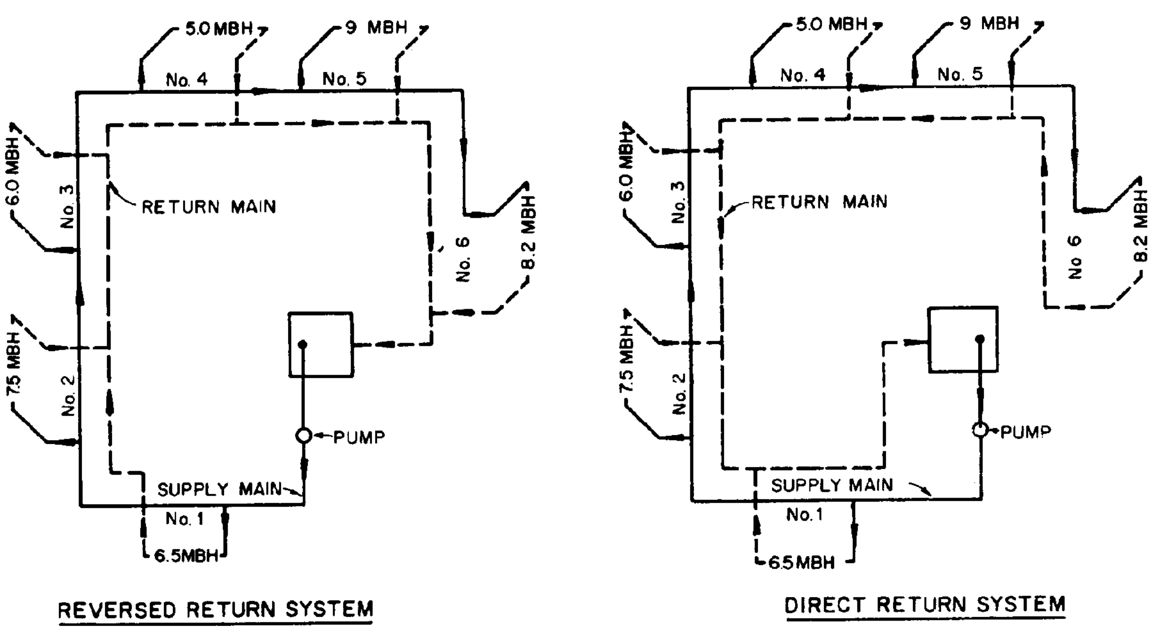

Figure 5-4. Two-pipe distribution system.

a. Direct return systems (figure 5-4.2). The heating units of the two-pipe, direct return system are in parallel. Water taken from the main to feed the first unit is returned first; that removed for the second unit is returned second; and so forth throughout the heating units. Since this procedure causes a progressively greater friction loss in additional circuits, the flow circuits are hydraulically unbalanced. This condition may cause the first unit to have a greater flow than is required to develop its full capacity, while, in a large system, flow through the last unit may be so small that practically no heat is delivered. Restricting orifices or throttle valves are sometimes used to correct flow distribution and to balance the system after it is placed in service.

b. Reversed return systems (figure 5-4.1). In the two-pipe reversed-return system, water taken from the main to feed the first unit is returned last to the return main; the water supplied to the last unit is returned first. As a result, all unit circuits are approximately equal in length, a condition conducive to system balance. The reversed return system may require more pipe than the direct return; however, its inherently better flow distribution and natural balance without the aid of additional valves or orifices, compensate for the additional cost.

c. Series-loop systems (figure 5-5). A series-loop system may have one or more loops or circuits. All the heating units in a circuit are installed in series and the same amount of water flows through each and through the connecting main. For a given available head, the length of the circuit and the number and type of heating units determine the water flow rate and temperature drop. The water temperature decreases progressively as the water flows through each successive heating unit. Series systems are frequently used in connection with baseboard radiation. Neither the flow nor the temperature of the water supplied to individual heating units can be regulated in this system. Delivery of heat, therefore, is usually controlled by air dampers in the baseboard radiation cabinets.

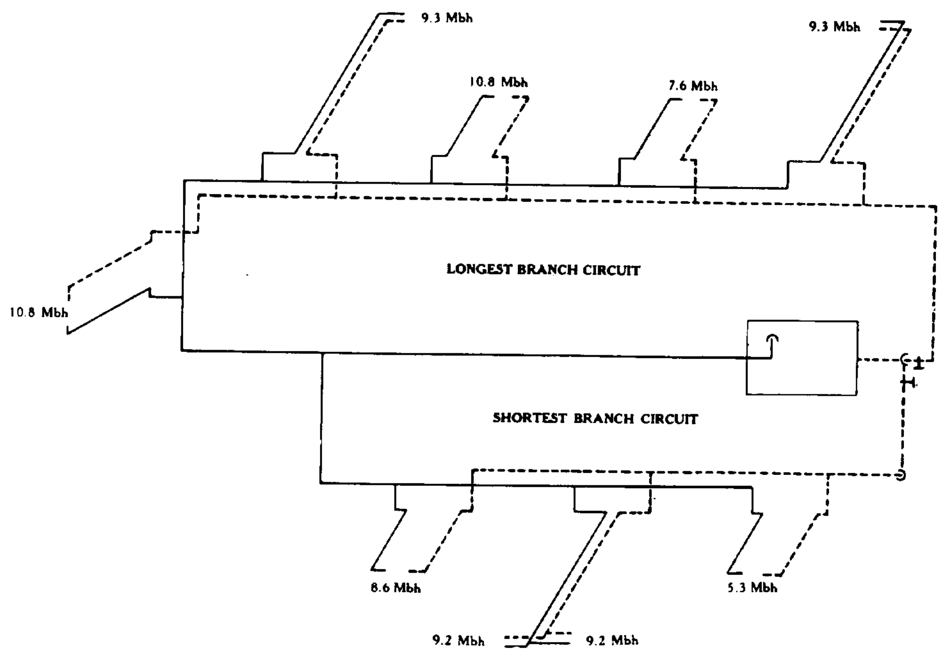

Figure 5-5. Series loop distribution system.

5-9. Inspection and maintenance.

Generally, a good hot water heating system rarely presents operating difficulties if temperatures and pressures are kept within normal ranges. If rapid fluctuation or pulsation pressures should occur, check for system leaks, stoppages, and relief valve operation. The indicated pressures of a closed system may increase slightly with the increase of water temperature. Each system has its own definite increase characteristic, determined by the water capacity of the system and the size of the expansion tank. Observe and record this characteristic when the system is in perfect operating condition. Any later deviations from the established pressure may indicate that the water level is low (if pressure decreases) or that the system is stopped or plugged (if the pressure is above normal). When a system is to be removed from service, drain the system completely of accumulated sediment, rust, and the like, and refill with clean water.

Section III. HOT WATER FAN-COIL UNITS

5-10. General.

a. Basic elements of fan-coil units are a finned-tube coil and a fan section (figure 5-6). The fan section recirculates air continuously from within the space through the coil which contains hot water. The unit may also contain chilled water or an electric resistance, steam, or hot water type of heating coil. A cleanable or replaceable low efficiency filter is located upstream of the fan. This filter prevents the coil from becoming clogged with dirt or lint entrained in the recirculated air. It also protects the motor and fan, and reduces the level of airborne contaminants within the conditioned space. The unit is equipped with an insulated drain pan. The fan and motor assembly is arranged for quick removal to facilitate servicing. Ventilation air boxes with a dampered opening for connection to openings in the outside wall are optional.

b. Room fan-coil units are available in a number of physical configurations. Figure 5-7 show several arrangements of vertical wall mounted units and a horizontal ceiling mounted model. Low vertical units are available for use under windows with low sills; however, in some cases the low silhouette is achieved at a compromise of such features as filter area, motor serviceability, and cabinet style.

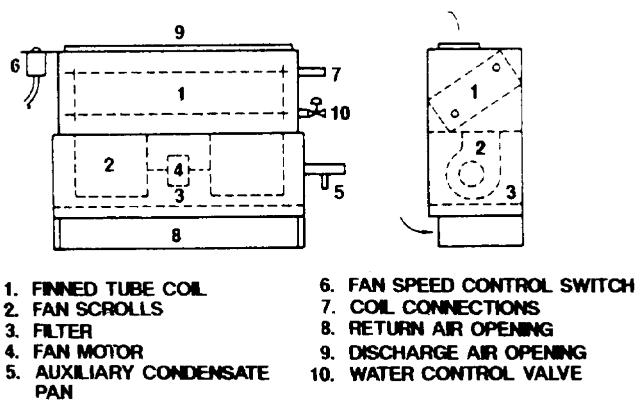

Figure 5-6. Typical fan-coil unit.

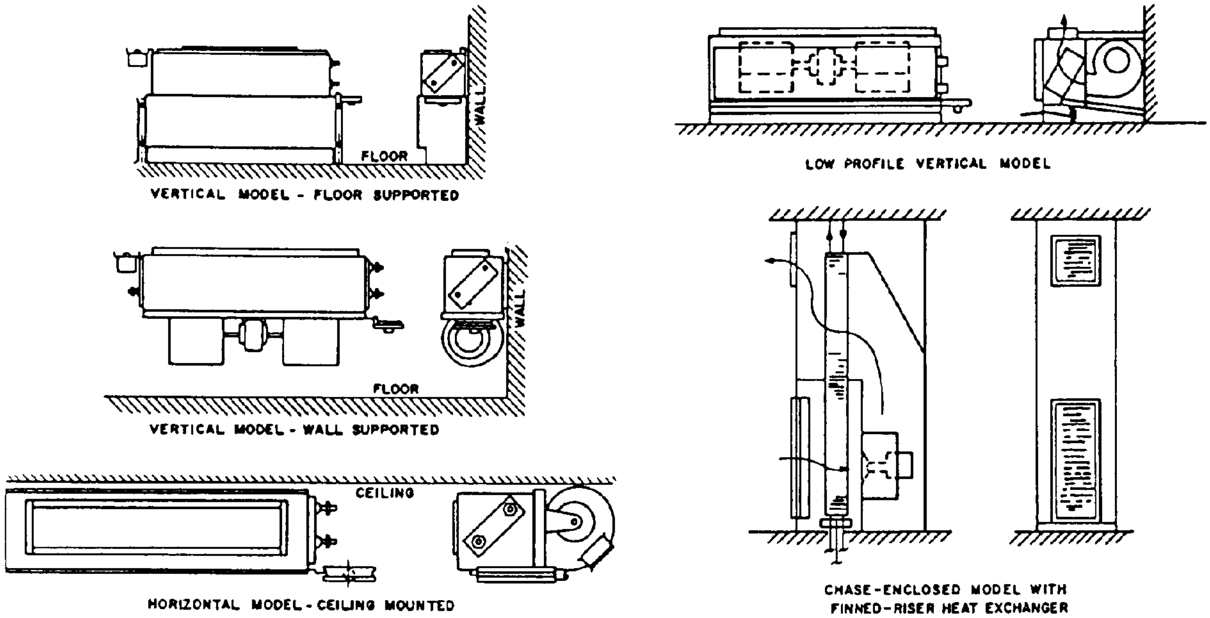

Figure 5-7. Typical fan-coil unit arrangements.

c. Floor-to-ceiling chase-enclosed units are available in which the water and condensate drain risers are part of the factory furnished units. If the riser is located in the partition between two rooms, both rooms can be served by the same unit. One style combines the water risers and coil into one assembly by finning a portion of the water riser. Water flow is continuous through all units and air bypass room temperature control is used. A limitation of this style of unit is the size of the finned riser; usually only 10 or 12 floors can be stacked on a common riser. Another style of floor-to-ceiling unit overcomes this limitation by using a separate coil which is sized independently of the risers.

d. Horizontal overhead units may be fitted with ductwork on the discharge to supply several outlets. A single unit may serve several rooms, e.g. in an apartment house where individual room control is not essential and a common air return is feasible. High static pressure units with larger fan motor handle the higher pressure drops of units with ductwork.

5-11. Fan coil capacity control.

a. Fan coil unit capacity can be controlled by coil water flow, air bypass, fan speed, or a combination of these. Water flow can be thermostatically controlled by either return air or wall thermostats. Modulating valves provide superior temperature control. Two-position valves cost less and provide superior dehumidification.

b. Water control valves should not be used where aperture outdoor intakes are used, unless there is a provision for freeze protection. Capacity control is achieved in certain configurations, by modulating a damper to bypass all or part of the air around the unit coil.

c. Fan speed control may be automatic or manual. Automatic control is usually on-off with manual speeds selection. Some units are equipped with variable speed motors for modulated speed control. Room thermostats are preferred where fan speed control is used. Return air thermostats will not give a reliable index of room temperature when the fan is off.

d. If horizontal units are installed, air velocity must be maintained to reach (throw) to the outside wall area, and manual readjustment of fan speed may be undesirable.

5-12. Electrical requirements.

a. Fans in these units are driven by small motors generally of the shaded pole or permanent split capacitor (PSC) type, with inherent overload protection. Operating wattage of even the largest sizes rarely exceeds 300 watts at the high speed setting. Running current rarely exceeds 2.5 amps. Almost all of the motors on units sold in the U.S. are wired for 115 V, single phase, 60 Hz current, and provide multiple (usually three) fan speeds and an off position. Voltage supply varies with each country, with 50 Hz current being quite common.

b. Separate electrical circuits, connected to a central panelboard, enable the building operator to turn off unit fans from a central point during unoccupied hours. While this results in a higher first cost, it offers operating cost advantages in buildings that do not have 24-hour per day occupancy. Use of separate electrical circuits is advantageous in applying a single remote thermostat mounted in a well exposed perimeter space to operate unit fans, if the setback temperature cannot be maintained with gravity heating. Connection of the fan-coil units into the lighting circuit serving the space results in a lower first cost and is satisfactory where air conditioning is being added to existing buildings.

5-13. Maintenance.

a. Room fan coil units are equipped with either cleanable or throw-away filters, which should be cleaned or replaced when dirty. Good filter maintenance improves sanitation and cleanliness and assures full air flow through the unit and hence full capacity. The frequency of cleaning will vary with the application. Units installed in housing facilities and hospitals usually require more than normal filter service due to the presence of lint. Adhesive coated filters are not advisable if unit fans can be off for extended periods during the heating cycle. Heat radiated to filters during these periods can cause vaporization of the adhesive, resulting in objectionable odors.

b. Fan coil unit motors require periodic lubrication. Motor failures are uncommon, but when they occur it is possible to quickly replace the entire fan deck, with little interruption within the conditioned space. The defective motor can then be repaired or replaced in the maintenance shop. The condensate drain pan and drain system should be periodically cleaned or flushed to prevent overflow. The airside of the coil should be cleaned annually.

Section IV. HEAT EXCHANGERS

5-14. General.

The term heat exchangers is usually applied to a device in which two fluid streams, separated by a solid surface, exchange heat energy. These devices may take many forms. However, ordinary metal tubes are the main components of many types. Heat exchangers in hot water systems can use steam or high temperature hot water from a central plant to generate the low temperature water needed for the heating systems.

5-15. Installation.

a. Provide sufficient clearance at the stationary tube sheet end of the unit to permit removal of tube bundles from shells. On the packed floating tube sheet end, a space of 3 or 4 feet should be provided to permit the removal of the rear head, packing and retainer rings.

b. Provide valves and bypasses in the piping system so that both the shells and tube bundles may be bypassed to isolate the unit for inspection or repairs.

c. Provide a thermometer well and pressure gauge connection in all piping to and from the unit and locate as near the unit as possible.

d. Provide necessary air vent cocks for units so they can be purged to prevent or relieve vapor or gas binding of either the tube or the shell sides.

e. Foundations must be adequate so that exchangers will not settle and cause piping strains. Foundation bolts should be set to allow for setting inaccuracies. In concrete footings, pipe sleeves at least one size larger than bolt diameter slipped over the bolt and cast in place are best for this purpose, as they allow the bolt center to be adjusted after the foundation has set.

f. Loosen foundation bolts at one end of unit to allow free expansion of shells. Oval holes in foundation brackets are provided for this purpose.

g. Set exchangers level and square so that pipe connections may be made without forcing.

h. Inspect all openings in exchanger for foreign material. Remove all wooden plugs and shipping pads just before installing. Do not expose units to the elements with pads or other covers removed from nozzles or other openings since rain water may enter the unit and cause severe damage due to freezing.

i. Be sure entire system is clean before starting operation to prevent plugging of tubes with sand or refuse. The use of strainers in settling tanks in pipe lines leading to the unit is recommended.

j. Drain connections should not be piped to a common closed manifold.

k. Water hammer can cause serious damage to the tubes of any heat exchanger. A careful consideration of the following points before an installation is made can prevent costly repairs which may be caused by water hammer.

(1) A vacuum breaker and/or vent, should be used in accordance with the type of steam system installed.

(2) The proper trap for the steam system installed should be used.

(3) The trap and the condensate return line to the trap should be properly sized for the total capacity of the convertor.

(4) The trap should be sized for the pressure at the trap, not the inlet pressure to the steam control valve.

(5) Condensate should be piped and pitched to the condensate receiver, condensate return pump or drain at an elevation below the heat exchangers. ***CAUTION:*** During times of shut down, volumetric expansion can occur. Therefore, the installation of a properly sized valve on the heated side of the exchanger, is essential.

5-16. Operation.

a. When placing a unit in operation, open the vent connections and circulate the cold medium only. Be sure that the passages in the exchanger are entirely filled with the cold fluid before closing the vents. The hot medium should then be introduced gradually until all passages are filled with liquid, then close vents and slowly bring the unit up to temperature.

b. Start operation gradually. Do not admit hot fluid to the unit suddenly when empty or cold. Do not shock unit with cold fluid when unit is hot.

c. In shutting down, flow of hot medium should be shut off first. If it is necessary to stop circulation of the cooling medium then the circulation of hot medium should also be stopped by bypassing or otherwise.

d. Do not operate equipment under conditions in excess of those specified on the name plate.

e. Drain all fluids when shutting down to prevent freezing and corrosion. To guard against water hammer, condensate should be drained from steam heaters and similar apparatus both when starting up and when shutting down.

f. In all installations there should be no pulsation of fluids since this causes vibration and strain with resulting leaks.

g. All gasketed joints should be checked for leaks and tightened if necessary soon after starting.

5-17. Maintenance.

a. Do not open heads until all pressure is removed from the system and the the heat exchanger is drained.

b. Do not blow out heat exchangers with air when fluids normally handled are inflammable.

c. To clean or .inspect inside of tubes, remove channel cover and rear head. On exchangers having bonnet type heads (without channel cover), piping must be disconnected and both heads removed.

d. Exchangers subject to fouling or scaling should be cleaned periodically. A light sludge or scale coating on the tube greatly reduces its effectiveness. A marked increase in pressure drop and! or reduction in performance usually indicates cleaning is necessary, unless air or vapor binding is the cause of the problem. Since the difficulty of cleaning increases rapidly as the scale thickens or deposit increases, the interval between cleanings should not be excessive. Cleaning should be performed as follows:

(1) Circulate hot wash oil or light distillate through tubes or shell at good velocity to remove sludge or other similar soft deposits.

(2) To remove soft salt deposits, wash out by circulating fresh hot water.

(3) Special cleaning compounds are available for removing scale or sludge, provided hot wash oil or water, as described above, does not give satisfactory results. These cleaning compounds, especially those containing acid, must be thoroughly rinsed from the heat exchanger after cleaning or rapid corrosion may result.

(4) If none of the above described methods are effective for the removal of hard scale or coke, use a mechanical means for cleaning, such as tube scraping.

(5) Do not attempt to clean tubes by blowing steam through individual tubes. This overheats the tube causing expansion strain and possible tube leakage.

Section V. ENERGY CONSERVATION

5-18. Hot water temperature reduction.

In addition to energy savings through the proper installation and maintenance of piping and equipment insulation, heat losses can be further reduced by reducing the hot water temperature to the minimum value required by the heating load and distribution heat losses. The hot water supply temperature should be reset (manually or by automatic control) proportional to the heating demand. Once other energy conservation measures have been implemented, the maximum hot water temperature requirement should be established by reducing the temperature step-wise during periods of maximum heating demand and noting the effect upon space temperatures. With this maximum temperature established, a linear reset schedule can be determined by noting the outdoor temperature corresponding to zero heating demand. Shut down boilers and heat exchangers completely whenever the outside temperature exceeds 65 F.

5-19. Night setback.

Setting back space temperatures at night will save a significant amount of energy. In large buildings with a central hydronic heating system, setback is usually performed by reducing the supply temperature from the boiler or heat exchanger at night. Another method of night setback uses a thermostat located in a part of the building which roughly represents the temperature of the entire building. This thermostat cycles the boiler or reduces supply temperature to maintain the desired setback temperature throughout the building.